BUREAU OF SUGAR EXPERIMENT STATIONS

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YEAR 1960, Nos. 1, 2, 3 and 4

No. 1. Gravimorphism in Sugar Cane
by
J. C. SKINNER

No. 2. A Wilt Disease of Velvet Bean
by
O. W. STURGESS and B. T. EGAN

No. 3. Studies with Chlorotic Streak Disease of Sugar Cane
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by
K. C. LEVERINGTON

Issued by Direction of the Sugar
Experiment Stations Board

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Gravimorphism in Sugar Cane

By J. C. SKINNER

SUMMARY

The effect of orientation on sugar cane was studied by maintaining potted plants in a horizontal position and by bending over stalks of a variety growing in the field. In the more critical field experiment the horizontal stalks showed a loss of apical dominance and a marked reduction in growth, two phenomena which are characteristic of gravimorphism. The number of nodes was not affected, but the horizontal stalks produced much shorter internodes and leaf sheaths. The experiments did not provide conclusive evidence about the third gravimorphic effect, induction of flowering. However, the results indicated that flowering may probably be induced in sugar cane by this method, provided that other conditions such as day-length and temperature are favourable.

INTRODUCTION

The effects of gravity on growth, apical dominance and flowering of fruit trees has been investigated by Wareing and Nasr [6], who found that the keeping of trees in a horizontal position reduced growth, eliminated apical dominance, and induced flowering. They introduced the term "gravimorphism" to describe these phenomena. Gravimorphism is clearly related to geotropism, which is used to describe the effects of gravity on growth curvature. Longman & Wareing [5] found that growth and flowering of the forest tree *Larix leptolepis* was much influenced by the position of the branches in relation to the gravitational field, the greater the branch angle from the vertical the heavier the flowering.

Induction of flowering by this treatment may have important applications in plant breeding, especially for crops such as sugar cane in which cross-pollination is necessary to produce new varieties, although commercial varieties are reproduced vegetatively. The cane breeder tends to discard free-flowering varieties during selection. As a result many commercial varieties do not flower, or rarely flower, and cannot be used for cross-pollination unless flowering can be induced.

The present communication describes two preliminary experiments on gravimorphism in sugar cane.

EXPERIMENTAL

Experiment I

The material for this experiment consisted of ten-month-old plants of the variety Q.67 grown in four-gallon steel drums. There were 24 drums of plants, with up to three stalks per drum. Q.67, which usually flowers fairly sparsely, was a suitable variety, but in other respects the material was not entirely satisfactory. The plants had been discarded from a disease transmission experiment in which sterilized and unsterilized setts had been planted in sterilized and unsterilized soil, six drums being used for each combination. It was subsequently found that the sett treatments had been about equally distributed in the gravimorphism experiment, but ten of the twelve drums of sterilized soil had been unintentionally included in the horizontal treatment. Probably this did not affect the gravimorphism experiment, but the possibility of bias cannot be excluded. Furthermore, the plants were badly root-bound and the vertical controls remained fairly waterlogged whereas horizontal drums drained readily, and also tended to become warmer because they were not shaded by the plants in them.

On 22nd April, 1959, twelve of the drums of plants were placed in a horizontal position, the remainder being left vertical as controls. The horizontal drums were occasionally rotated through 180° to stop the stalks bending upwards. They remained horizontal throughout the experiment, except for brief periods when they were watered.

During the experiment the horizontal plants grew more rapidly than the controls, but this was almost certainly due to better drainage and warmth rather than gravimorphism.

On 26th May, 1959, the stalks were sectioned and examined for floral initials, with the following results:—

Treatment	Flowering	Non-flowering
Vertical (control)	3	26
Horizontal	19	15

The departure from independence is highly significant statistically. All of the horizontal stalks showed a loss of apical dominance, side-shoots about eight centimetres long having developed on the younger nodes of each stalk, whereas none developed on the vertical stalks. Although it is of interest to record these two effects, the possibility that they might have been due to the different growing conditions already described, and not solely to gravimorphism should not be overlooked.

Experiment II

For a critical experiment it is necessary to ensure that horizontal plants differ from the vertical controls only in orientation. This is difficult with potted plants and it would be necessary to spend a year raising suitable plants.

A more exact comparison could possibly be made by bending over a few stalks of a variety growing in the field. A preliminary experiment with this method was carried out, using a border row of the hybrid variety U.S.48-34, which had been planted for propagation purposes in September, 1958. This variety usually flowers fairly sparsely and has flexible stalks which could be easily bent without breaking.

Eleven pairs of stalks were used, the stalks of each pair being close together in the row, and similar in growth and appearance. On 26th May, 1959, one stalk of each pair was bent below the horizontal position, the other stalk being left vertical as a control (Figure 1).

Figure 1.—Stalks of the variety U.S.48-34 were restrained in a horizontal position, similar labelled stalks being left vertical as controls.—Photo, J. H. Buzacott.

The bent stalks were kept under two horizontal sticks which were moved occasionally to prevent the stalks bending unduly or growing upwards through geotropism.

On 29th July five pairs of stalks were dissected and examined for flower initials. The remaining horizontal stalks were released and supported in the vertical position. On 1st September one typical pair of stalks was cut off and photographed (Figure 2).

Figure 2.—Effect of gravity on growth of sugar cane. In comparison with the normal vertical stalk (right), the stalk which had received the horizontal treatment produced much shorter internodes and a lateral shoot developed, indicating a loss of apical dominance. The top of this stalk appears to be going up to flower, but it did not contain any floral initials.
—Photo, J. H. Buzacott.

The remaining five pairs of stalks were measured on 28th September, 1959, and the growing points dissected.

No floral initials were present in any of the treated or control stalks (eleven pairs). Long side-shoots developed on four of the six horizontal stalks which had been allowed to resume the vertical position, whereas none developed on the vertical controls.

The stalks which received the horizontal treatment averaged 18.3 cm. shorter than the vertical control stalks. The standard error of this difference was 2.9 cm. so the reduction in elongation was statistically significant ($P < 0.01$). The treated and control stalks did not differ in node number, the "horizontal" stalks averaging 0.8 more nodes, an insignificant amount. The effects of the horizontal treatment on internode length and leaf sheath length are shown in Figure 3.

The reduced length of the horizontal stalks was due to a marked and highly significant reduction in internode elongation, and leaf sheath elongation was also very much reduced. Both of these organs tended to resume normal growth when the stalks were allowed to return to the vertical position.

DISCUSSION

Although flowering was significantly greater in the horizontal plants than in the vertical controls in Experiment I, it cannot be concluded with

certainty that flowering was induced by the horizontal orientation, because the experimental design did not exclude all other possibilities. No flowering was induced in Experiment II, but in this case the treatment was applied in winter, when flower initiation does not normally occur.

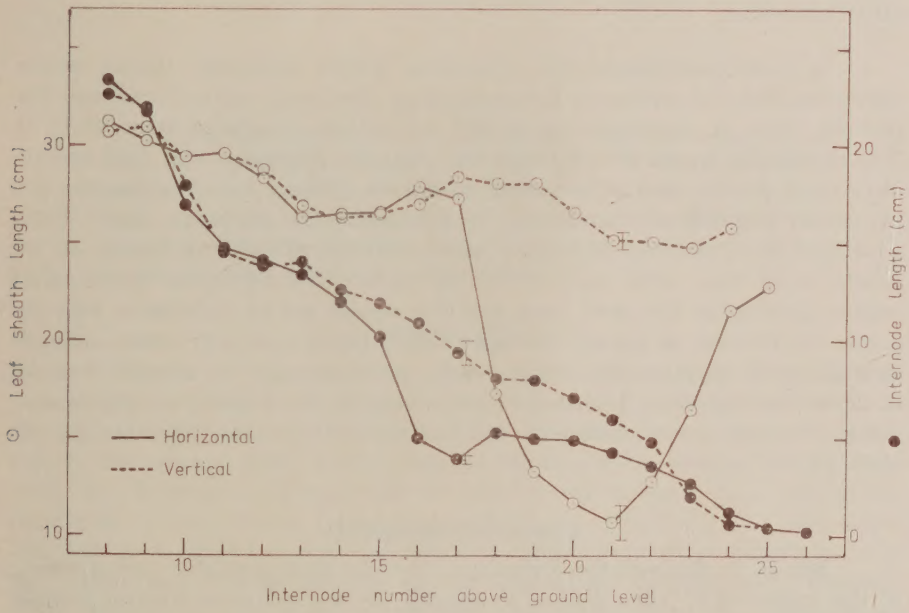

Figure 3.—Effect of gravity on internode length and leaf sheath length of sugar cane. Five stalks receiving each treatment were measured, the mean values being shown. The length of the vertical black lines at internode numbers 17 (internode length) and 21 (leaf sheath length) represent twice the standard errors of the mean values, plotted with the mean as midpoint.

Flowering of sugar cane is a photoperiodic response [3], the optimum photoperiod being about 12½ hours [2]. Flowering is supressed by long days, and it may also be supressed if the days are too short [1].

Once the photoperiodic requirements are satisfied, flowering is limited by other environmental and physiological factors which are not completely understood. The operation of one or more such factors is shown by the fact that sugar cane normally flowers in winter and not in summer, although suitable photoperiods occur both in autumn and spring. Temperature is probably an important factor in flower initiation. Brett [1] found that sugar cane exposed to twelve-hour photoperiods flowered more freely at a night temperature of 23°C than at 28°C. In Queensland minimum temperatures of about 22°C occur during the beginning of flower initiation in autumn and, although the effect of temperature on flower initiation has not been investigated experimentally, practical experience indicates that cold weather in autumn supresses

flowering. The absence of flowering in Experiment II shows that gravimorphism cannot replace requirements such as suitable daylengths and temperatures, but does not exclude the possibility that flowering may be induced by gravimorphism under more favourable environmental conditions. Further experiments with this technique will be carried out during the normal autumn initiation period.

In both experiments the horizontal stalks produced lateral shoots, indicating that the treatment had reduced or eliminated apical dominance. The marked effect of orientation on growth was shown clearly in Experiment II. The number of nodes was not affected, but the internodes and leaf sheaths were much shorter in the horizontal treatment (Figure 3). The sheaths and internodes affected differed in age, each reduction in internode length being paralleled by a corresponding and more marked reduction in length of the sheath about four units above it on the stalk. The treatment would affect organs growing at the same time, and the results are in accordance with the known distribution of growth in sugar cane. Growth in each organ proceeds in a basipetal direction and, consequently, accomplishment of growth proceeds in the order: leaf blade, leaf sheath, and internode, the stage of growth of each young internode corresponding to the leaf sheath four units above it on the stalk [4].

ACKNOWLEDGMENT

Mr. B. T. Egan of the Pathology Division made available potted plants of the variety Q.67, thus making it possible for the writer to conduct Experiment I. This assistance is gratefully acknowledged.

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A Wilt Disease of Velvet Bean caused by *Phytophthora drechsleri* Tucker

By O. W. STURGESS and B. T. EGAN

SUMMARY

The cultural characteristics, pathogenicity and host range of a strain of *Phytophthora dreschleri* are described. In Queensland, this species causes a stem rot and wilt condition of velvet bean (*Stizolobium* spp). Symptoms and field spread of the disease are outlined. Field and glasshouse tests show that cultivated types of velvet bean do not possess genetical resistance to this disease.

INTRODUCTION

Within recent years velvet beans (*Stizolobium* spp.) have become increasingly important as a green manure crop for sugar-cane land in Queensland. One of the attractions of this legume in comparison with members of the cowpea group was its relative freedom from disease. In January, 1957, [3] however, a killing stem rot and wilting occurred in a well grown crop near Cairns, North Queensland and in the following year two other localities were also found to be infected. Recently further infections have been found and another planting on the original site became badly diseased. Work detailed in this paper shows that the causal agent is *Phytophthora drechsleri* Tuck.

Bates [2] had reported a similar disease causing losses in velvet beans in the Federation of Rhodesia and Nyasaland. This, which was referred to as a root and vine rot, was shown to be due to *P. drechsleri* [1].

SYMPTOMS

Affected plants exhibit a range of symtoms which vary according to the site of infection and the stage of plant and disease development. Velvet bean seedlings may suffer pre-emergent death or a wilt condition at the two-leaf stage; older plants usually show early symptoms in tissues at or near ground level. Affected stems and roots develop a black discoloration at the site of infection, followed by the formation of a slightly depressed lesion which extends rapidly, particularly in young tissues. On stems and branches this results in a girdling of the affected areas. The foliage of diseased plants may gradually yellow as a result of primary leaf infection or suddenly wilt as a result of stem or branch girdling. The lower leaves of affected plants usually abscisss whilst leaves at a distance from the site of infection are affected by the girdling action of the pathogen; they remain attached to the plant and, after a wilt phase, develop a papery, brown necrosis.

FIELD SPREAD

In the outbreaks so far observed, the disease has spread on irregular fronts away from foci of infection. There is the development of a central area of dead plants, surrounded by a narrow but variable band of wilted and yellowed plants which quickly grade off into healthy plants. However, isolated diseased plants may be found scattered ahead of the main front or throughout the affected planting, especially along any drainage channels.

CAUSAL ORGANISM

Isolations from the edge of stem lesions consistently yielded a species of *Phytophthora;* sundry other fungi, the commonest being *Fusarium* spp., were also obtained. Such species tended to overrun the slower growing phycomycete in plate cultures; pure cultures were obtained by utilizing the selective action of inoculated apple fruit.

The pathogenicity of the *Phytophthora* isolates in unwounded velvet bean plants was confirmed by the stem-inoculation technique described by Weimer [6]. Wound inoculation of velvet bean stems was readily obtained by needle pricking. Black necrotic lesions developed at the site of infection after a lapse of four to seven days; all plants eventually wilted and collapsed due to the fungal attack, a *Phytophthora* was re-isolated from the affected plants whilst the control series of velvet bean plants remained healthy.

A study of the morphology and cultural characteristics of the causal organism led to the conclusion that the isolates were of *Phytophthora drechsleri* Tuck.; this was confirmed by the Commonwealth Mycological Institute, Kew.

The causal organism did however, exhibit variability from the type species described by Tucker [5]. Sporangia measured 58.3μ by 38.2μ, with a range of (50.1 — 72.9μ) by (36.4 — 45.6μ) and were rarely initiated in culture or on diseased velvet bean plants despite the application of varied techniques designed to stimulate sporangial initiation.

Zoospores averaged 13.3μ (11.0 — 17.6μ) in diameter and their development within mature sporangia was exceedingly slow; they were imperfectly differentiated within the sporangium and generally were extruded in mass through the non-papillate opening; in one particular instance, zoospores were seen to differentiate within the sporangium and germinated *in situ* with germ tubes penetrating the sporangial wall. On some other occasions direct germination of the sporangium was observed.

Oogonia which measured 32.1μ (27.3 — 37.4μ), amphigynous antheridia and oospores measuring 30.3μ (20.4 — 36.4μ) developed in abundance on corn meal agar, less so on oatmeal agar and sparsely on potato dextrose agar.

The optimum temperature for growth of the velvet bean isolates on corn meal agar slopes was found to lie between 28.4°C. and 30.0°C. and growth ceased at 39.5°C. These figures are in agreement with those for the type species.

The Commonwealth Mycological Institute reported that the Queensland isolates of *P. drechsleri* were somewhat unusual in that they form sex organs readily in single culture (*P. drechsleri* usually needs to be grown with another strain) and that they do not form sporangia very readily on agar material transferred into water. Sporangia were obtained by culturing the fungus on seeds.

RESISTANCE TRIALS

At Aloomba, near Cairns in North Queensland, a disease resistance trial was planted to determine the reaction of four velvet bean varieties and eight cowpea varieties to *P. drechsleri*. The trial site had previously grown a diseased cover crop of velvet beans. The assessment of the varietal reaction to the disease was recorded over the short period of five weeks which was available between the end of the "wet" season and the planting of cane setts.

The velvet bean varieties — Stringless, Somerset, Crew and an un-named variety, showed from 80 to 100 per cent. infection whilst the cowpea varieties - Black, Black Eye No. 5, Havana, Malabar, Reeves, Souther, C.P.I. 8085 and 8086 remained healthy.

Owing to the then restricted outbreaks of the disease in field plantings, velvet bean varieties were subsequently tested for their disease reaction in pots which were maintained under glasshouse conditions. Seeds of all available varieties and un-named selections were planted in steam-sterilized soil. Two methods were employed to ascertain the plant reaction to the pathogen; one was described by Purss [4] and the other, as follows : — a cornmeal-sand culture of *P. drechsleri* was mixed with the upper soil layer to a depth of one inch, prior to the sowing of surface-sterilized seeds. Control plantings were included to assess seed viability and to estimate pre-emergent losses of seedlings.

All plants of the available twenty-two varieties or selections succumbed to the pathogen and pre-emergent losses in the soil-inoculation series were high, to the extent of 100 per cent. in most varieties. Seedlings which escaped pre-emergent death, invariably collapsed at the two leaf stage.

Whiteside (personal communication, 1957, from South Africa) has reported that velvet bean material resistant to the root and vine rot disease caused by *P. drechsleri* has not been located by planting local varieties together with other varieties from Portuguese East Africa and the U.S.A. on infected soil.

The results of glasshouse and field trials in Queensland supported by the results from South Africa, indicate an absence of genetical resistance to *P. drechsleri* within the cultivated types of velvet bean. The South African pathologists are continuing their search for resistance within the wild species of velvet bean some of which are indigenous to Central Africa.

HOST RANGE

The presence of *P. drechsleri* in a number of cane fields in North Queensland necessitated the checking of cane varieties in the field and glasshouse to determine the reaction of sugar cane (*Saccharum* spp.). By inoculation, cane setts and stalks were found to be immune to the organism, and field observations of cane plantings in the diseased areas support the routine inoculation results.

A wide range of legume species was tested against the pathogen. The following species were not infected by the soil inoculation technique:—*Cajanus cajan* (L.) Millsp., *Centrosema pubescens* Benth., *Crotalaria goreensis* Guill. and Perr., *Cyamopsis tetra-gonoloba* (L.) Taub., *Glycine javanica* L., *Leucaena glauca* (L.) Benth., *Medicago lupulina* L., *M. sativa* L., *M. tribuloides* Desr., *Phaseolus calcaratus* Roxb., *P. lathyroides* L., *P. munga* L., *Pisum arvense* L., *Pueraria phaseoloides* Benth., *Stylosanthes gracilis* H.B.K., *S. sundaica* Taub., *Trifolium alexandrinum* L., *T. fragiferum* L., *T. glomeratum* L., *T. incarnatum* L., *T. pratense* L., *T. repens* L., *T. subterraneum* L., *Vigna sinensis* (L.) Endl. ex Hassk., vars.—Malabar, Giant Poona, Cristaudo, Black, Reeves' Selection.

Lupinus angustifolius L., var.—New Zealand Blue proved to be susceptible to *P. drechsleri*.

A number of fruits were infected by wound inoculation; they were watermelon (*Citrullus vulgaris* Schrad.), tomato (*Lycopersicon esculentum* Mill.) and eggfruit (*Solanum melongena* L.). Potato (*Solanum tuberosum* L.) tubers were not infected by the velvet bean isolate of *P. drechsleri* through wounded or unwounded surfaces.

LONGEVITY OF THE ORGANISM IN THE SOIL

In South Africa, the fungus has been shown to persist in the soil for periods up to five years during which time the affected fields were planted with maize and other immune crops. In Queensland, a number of pots, complete with soil, used for pathogenicity and disease resistance tests were retained in the glasshouse and kept moist for an extended period. Up to the present, ten pots in two series have been checked for viable spores following a twelve and fifteen months lapse of time. Velvet bean plants established in each pot, succumbed to the wilt pathogen at varying stages of plant development. Re-isolations from diseased plants confirmed the identity of the organism.

ORIGIN OF THE DISEASE

The heavy demand for velvet bean seed during the last few years could not be met by the Australian seed producers. As a result of the seed shortage supplies were imported from South Africa, particularly to meet the requirements of sugar cane growers. In each case the occurrence of the wilt disease in velvet bean plantings has followed the use of South African or mixed Australian-South African seed.

As *P. drechsleri* has not been reported previously in Australia as a velvet bean pathogen, it is probable that viable oospores have been transported to the North Queensland plantings either in the pieces of vine trash present in the bags of South African seed or in the adhering dust.

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Studies with Chlorotic Streak Disease of Sugar Cane

1. Introductory Nutrient Solution Studies

By O. W. STURGESS

SUMMARY

Glasshouse experiments using nutrient solutions and gravel cultures showed that chlorotic streak disease could be transmitted from diseased to healthy plants when grown together in the one container, or when grown alternately in the one container without root contact.

INTRODUCTION

Investigations designed to elucidate the causal organism and methods of transmission of chlorotic streak disease of sugar cane have been undertaken in several countries since the discovery of the disease some 30 years ago [3, 8, 10]. The lines of research have been influenced by two hypotheses viz. *a*. that the causal agent is a virus [1] and *b*. that the causal agent is a fungus [5]. Whatever the type of organism involved it is obvious that the development of an efficient transmission technique is an important first step in the research on the disease.

Prior to 1950, several of the larger cane-growing districts in Queensland were free from chlorotic streak disease despite the existence of localities which, on experience in other parts of the State, would be expected to harbour the disease once it gained an entry. In the years 1953 to 1956, chlorotic streak was recorded for the first time [7] in the widely separated districts of Giru (North Queensland), Mackay (Central Queensland) and Bundaberg-Childers (South Queensland). Within a few years the disease was widespread in these districts and the indications were that flood, normal surface and drainage waters were implicated in the intra-district dispersal, particularly in plantings on soils which were prone to water-logging.

These observations on the field spread of the disease combined with the early investigations of Martin in Hawaii [9] and recent findings by Antoine in Mauritius [2] stimulated an approach to the problem based on the growing of diseased and healthy plants in nutrient solutions. Experiments of this type were commenced at Meringa (near Cairns, North Queensland) towards the end of 1957 and at Brisbane during 1958. The results reported below for the Brisbane work with aerated, non-aerated and gravel cultures confirm Martin's [9] transmissions and those of Bird *et alia* [4] in Puerto Rico. It is of interest that these experiments in Puerto Rico were running concurrently with those in Queensland. The results of the Meringa experiments will be published at a later date.

MATERIALS AND METHODS

Healthy cane buds were collected from the Pathology Farm, Eight Mile Plains [6], where chlorotic streak does not occur. Buds used as a source of chlorotic streak were selected from stalks showing prominent leaf symptoms in commercial cane fields. Seed pieces from healthy and diseased material were germinated separately in flats of steam-sterilized sand. Individual shoots were excised soon after the development of shoot roots and transferred to the respective containers. Only shoots showing symptoms were used for the diseased series.

One-gallon paint tins with lever lids were used for the solution cultures. Holes 1¼ inches in diameter were punched in the lids and the shoots were held in position by a plastic foam wrapping around the stalk. The aerial parts of the plants were held by cords suspended from overhead wires.

Water-worn river gravel washed in Brisbane city water and steam sterilized was used for the gravel cultures in two-gallon galvanised vessels.

The nutrient solution used in both solution and gravel cultures was as follows:—

Potassium chloride	0.149g
Di-potassium hydrogen phosphate	0.349g
Magnesium sulphate ($MgSO_4.7H_2O$)	0.493g
Calcium nitrate ($Ca(NO_3)_2.4H_2O$)	0.82g
Ammonium sulphate	0.132g
Iron-sodium sequestrol	0.035g
Copper sulphate ($CuSO_4.5H_2O$)	0.078mg
Zinc sulphate ($ZnSO_4.7H_2O$)	0.22mg
Manganese sulphate ($MnSO_4.4H_2O$)	2.03mg
Boric acid	1.43mg
Ammonium molybdate ($(NH_4)_6Mo_7O_{24}.4H_2O$)	0.01mg
Tap water	1 litre

The pH was adjusted to 6 by the addition of $N.H.SO_4$ but this initial pH drifted to 7.2, the normal figure for the City water supply, during uptake by the plants. No attempt was made to correct this drift.

Unless otherwise specifically stated all nutrient solutions in tins were aerated for five minutes every hour through an aquarium air-stone placed deep in the solution. The amount of air coming through to each container was controlled by a small clamp attached to the plastic air-line. Aeration in the gravel cultures was provided by the air space of two inches or so between the surface of the liquid and the surface of the gravel.

Nutrient solutions in all containers were changed once every two weeks. At other times the level of the solutions was maintained by the addition of either tap water or nutrient solutions, depending on the rate of shoot development. All secondary shoots were removed from the base of the primary stalks as they appeared.

The plants were sprayed regularly with malathion or parathion to control insect populations but a build-up of mealy bugs and mites did occur at times.

Experiment A, which was commenced on July 3rd, 1958, consisted of pairs, each of one diseased and one healthy shoot, growing together in the one container. The range of varieties used included N.Co.310, Pindar, Q.50, Q.58, Q.61, and Q.66 but only one variety was used in any one pair. Twenty-four pairs were placed in aerated nutrient solutions (Experiment A1), five in non-aerated solution i.e. without pressure aeration (A2) and nine in gravel cultures (A3). All plants were ratooned on January 6th, 1959, and maintained for a further period of four months.

Developments during the course of Experiment A prompted another experiment (B) of a slightly different type. In this, using buds of the varieties N.Co.310, Q.50, Q.61, Q.63, Q.66 and Q.70, two healthy shoots were grown in one tin of a pair of tins and two diseased in the other, and changes of plants from tin to tin within the pair made three times a week. The diseased and healthy shoots were not at any time together in the one solution. Twelve pairs of tins were arranged and the experiment was set up on December 18th, 1958. Plants were ratooned on July 22nd, 1959, and maintained for a further six months.

A minimum series of at least 20 healthy plants growing in pairs in the same tins were maintained during the course of both experiments as controls. They were ratooned at the same time as the experimental cane. In addition, 14 pairs of diseased and healthy plants were grown together in porous earthenware pots containing steam-sterilized soil as a further control against disease transmission by intimate plant contact or aerial vectors. These pots were not watered to excess and soil moisture was maintained at or below field capacity. They were ratooned on January 7th, 1959, and maintained for a further six months.

RESULTS

Details of the transmission obtained in Experiment A are set out in Table 1. Although 38 pairs of diseased and healthy shoots were set up, only 25 of these showed well defined symptoms after the initial check in growth due to severance from the setts; three (all in gravel culture) showed symptoms for a short period only; the remainder made normal growth without any expression of the disease. These apparently healthy shoots and the three showing transient symptoms were maintained with the remainder of the experiment but no transmission to the healthy partners occurred in these pairs. Eleven of the 25 originally healthy buds associated with continuously diseased shoots developed chlorotic streak, six of these first showed the disease in the plant cane, five in the ratoons.

TABLE 1.

Chlorotic streak transmissions from diseased to healthy plants in Experiment A.

Treatment	Variety	No. of pairs	Diseased plants expressing symptoms	Transmissions		
				Plant	Ratoon	Total
A1. (aerated solution)	N.Co.310	9	8	3	1	4
	Q.50	6	6	1	0	1
	Q.58	3	3	1	0	1
	Pindar	3	1	0	0	0
	Q.61	2	0	0	0	0
	Q.66	1	0	0	0	0
	Total	24	18	5	1	6
A2. (non-aerated solution)	Q.58	2	1	0	0	0
	Q.50	2	2	0	2	2
	N.Co.310	1	1	1	0	1
	Total	5	4	1	2	3
A3. (gravel and solution)	Q.58	3	2 + (?1)	0	2	2
	Q.50	2	(?1)	0	0	0
	N.Co.310	2	1 + (?1)	0	0	0
	Q.66	2	0	0	0	0
	Total	9	3 + (?3)	0	2	2
Grand Total		38	25 + (?3)	6	5	11

Although some transmission occurred in the non-aerated solutions, growth of the plants in them was not as satisfactory as in the aerated. In addition, reduction processes led to the production of metallic sulphides and also the evolution of hydrogen sulphide. It would appear, therefore, that aerated solutions are to be preferred to non-aerated at this juncture.

In Experiment B, in which diseased and healthy shoots were exchanged in the one solution and the roots of each series were never in contact, 11 out of 21 originally healthy plants contracted the disease. It is evident that this transmission occurred per medium of the solution, indicating that the causal organism is capable of existing in an infectious condition in the solution even though the roots of diseased plants have been removed. The organism could be suspended in the solution as independent entities but on the other hand, there is inevitably some debris left in the solution after removal of the plants and it is possible that the organism could be associated with this.

Healthy plants in the control solution series and in the control soil-planted series grew normally and remained free from the disease for the entire period of the experiments, although the shoots from diseased sources developed chlorotic streak as expected in the soil-planted series. The conclusion therefore appears warranted that the transmissions obtained were due to the placing of diseased and healthy shoots in the same containers of solution or solution plus gravel, although not necessarily at the same time.

The results of these glasshouse experiments show conclusively that chlorotic streak disease may be transmitted through nutrient solutions independently of root contact. They also support field observations on the role of surface waters in the transmission of the disease. Further investigations are in train.

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The Effect of Saline Conditions on the Growth of Sugar Cane

Part I. The Effect of Sodium Chloride

By K. C. LEVERINGTON

SUMMARY

Sugar cane was grown in sand cultures using nutrient solutions with osmotic concentrations of 0.5, 1.5, 2.5, 3.5 and 4.5 atmospheres. Reductions in growth of both roots and shoots were found to occur in the 2.5, 3.5 and 4.5 atmosphere treatments. A method for relating the results from nutrient cultures to field conditions is suggested.

INTRODUCTION

It has been known for many years that excessive amounts of soluble salts may severely inhibit the growth of sugar cane, but until recently only minor occurrences of saline areas had been recorded in the cane fields of Queensland. However, during the post-war expansion of the sugar industry many areas of marginal land were brought under cultivation, and it is in some of these areas that the problems of salinity have assumed considerable importance.

By comparing the specific electrical conductivity of the 1 : 5 soil-water suspension, hereafter termed conductivity index, with observed field conditions of growth, it has been possible to deduce approximate critical levels of salinity to be used in advisory work. However, as many of the saline areas have been found to contain appreciable quantities of magnesium and sulphate ions as well as sodium and chloride ions, it was felt that it was desirable to know more about the effects of specific ions on the growth of sugar cane.

Magistad et al. [1] reported that growth responses in salinized culture solutions are characteristic of plant growth in soil solutions of equal concentration and a number of workers have examined the effects in sand cultures of excessive amounts of various ions on tomatoes, beans, peas and flax [2], [3].

This paper describes the first of a series of experiments to be conducted in sand cultures to determine the effect of saline substrates on the growth of sugar cane.

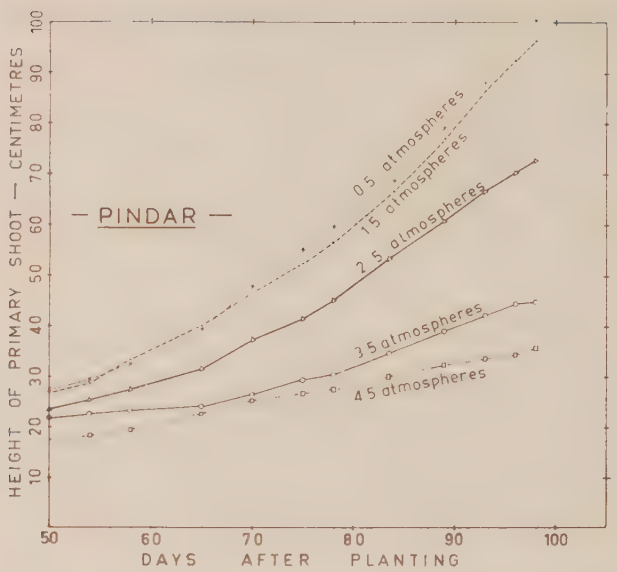

Figure 1. Showing the rate of elongation of the primary stalks of Pindar for the various treatments.

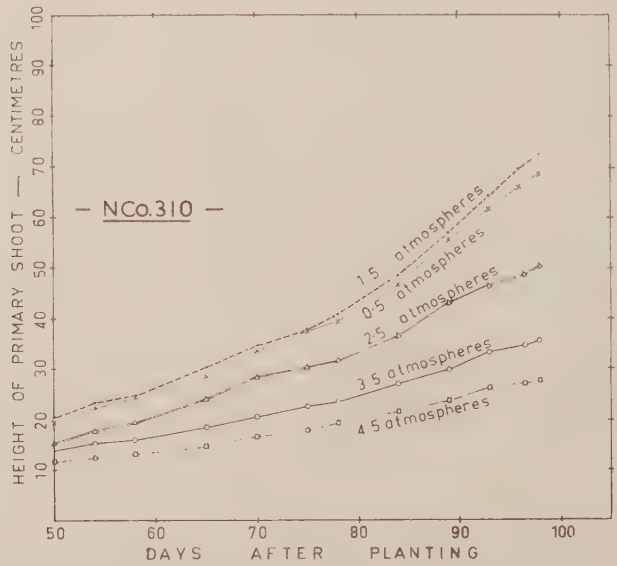

Figure 2. Showing the rate of elongation of the primary stalks of N.Co.310 for the various treatments.

MATERIALS AND METHODS

Single-eye seed pieces of the two varieties, Pindar and N.Co.310, were planted in washed river sand in four-gallon drums. Initially two setts of each variety were planted in each drum from which drainage was so arranged that a water-table, three inches deep, was maintained. One large reservoir of nutrient solution was provided for each treatment, and an automatic irrigating device controlled by a time clock pumped about one gallon of solution into each drum once every hour. With this method of circulation it was possible to maintain solutions of equal concentration in each of the four drums in a particular salinity series.

Figure 3. Showing the growth of cane fourteen weeks after planting. From left to right 4.5, 3.5, 2.5, 1.5, 0.5 atmospheres asmotic concentration. In each drum Pindar is on the right.

Five levels of salinity were used; viz., a control of basal nutrient solution with an osmotic concentration of approximately 0.5 atmospheres, and four other solutions made by the addition of sodium chloride to the basal nutrient solution to raise the osmotic concentrations to 1.5, 2.5, 3.5, and 4.5 atmospheres. The specific electrical conductivities of these five solutions were 1.40, 3.93, 6.50, 9.05, 11.55 millimhos per cm. respectively. Three times per week the concentrations of the solutions were checked and adjustments to bring them back to their correct osmotic concentration made where necessary. Complete changes of the nutrient solutions were made at intervals varying between one and two weeks depending on the stage of growth of the plants.

Seven weeks after the start of the experiment the number of plants in each drum was reduced to one of each variety. At this stage growth measurements were commenced and continued at regular intervals until the conclusion of the experiment in mid-January seven weeks later. The height of the shoots was measured from the sand surface to the highest visible dewlap.

RESULTS AND DISCUSSION

Germination was reasonably even and the initial growth in the high salt treatments was equal to that in the control series. However, by four weeks after planting it was apparent that the growth rates in the 3.5 and 4.5 atmos-

phere series had been checked, and when plants were removed at seven weeks it was obvious that both root and shoot development had been retarded by the higher levels of salinity.

Figures 1 and 2 are graphical representations of the growth measurements of the plants and indicate the deleterious effects of the solutions containing the higher levels of sodium chloride. At no stage during the experiment were there noticeable differences in growth between the control series and the 1.5 atmosphere series, although at osmotic concentrations greater than 1.5 atmospheres there was a progressive inhibition of growth with increasing salinity. With the 2.5, 3.5 and 4.5 atmosphere treatments the rates of stem elongation relative to that of the control decreased with time.

Table 1 sets out for the various treatments the average weights of the roots, the average weights of the above-ground parts and the average heights of the primary shoots at the conclusion of the experiment. The effects of the higher levels of salinity are again apparent by the reduction in weight of the plants. This effect may be somewhat accentuated in this table as the above-ground parts of the 3.5 and 4.5 atmosphere treatments consisted mainly of green tops, whereas similar parts from the control and 1.5 atmosphere treatments also included a considerable amount of millable stalk. The relative differences in weight therefore may be greater at this early stage than at maturity.

Figure 4. Showing the root systems of Pindar fourteen weeks after planting. From left to right 4.5, 3.5, 2.5, 1.5, 0.5 atmospheres osmotic concentration.

Figures 3 and 4 illustrate the differences in growth due to the various treatments fourteen weeks after planting.

This initial experiment has shown that serious reductions in the growth of sugar cane can take place at relatively low concentrations of sodium chloride in a nutrient solution. If a soil solution with an osmotic concentration of sodium chloride of 2.5 atmospheres is considered to cause marked reductions in growth it is possible to draw up a table indicating the moisture contents at which this concentration will occur for soils of various conductivity indices. Table 2 shows the moisture contents at which serious growth inhibition should occur for soils whose conductivity index lies within the range of 0.15 to 0.5 millimhos/cm.

TABLE 1

Effect of various osmotic concentrations on the heights and weights of cane fourteen weeks after planting.

Osmotic concentration of nutrient solution (atm.)	Height (cm)		Weight of shoots (g)		Weight of roots (g)	
	N.Co.310	Pindar	N.Co.310	Pindar	N.Co.310	Pindar
0.5	68	100	245	466	70	115
1.5	72	96	258	408	84	102
2.5	50	73	151	246	42	94
3.5	35	45	88	100	30	53
4.5	28	36	63	86	30	46

TABLE 2

Moisture content at which soils of various conductivity indices will have a soil solution with an osmotic concentration of 2.5 atmospheres.

Conductivity index (mmhos/cm)	Moisture content per cent.
0.15	12
0.2	16
0.3	24
0.4	32
0.5	40

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